Modelling crop-livestock integration systems at a farm scale in a Highland region of Madagascar: a conceptual model

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Introduction

Malagasy Highland region of Vakinankaratra (19°51'S; 47°01'E) is the heart of the Madagascar dairy basin and generates 90% of the national dairy production. Farms are based on diverse crop rotations, where rise is the main crop, and livestock activities (dairy cows, zebus, pigs, poultry, etc.). The milk is produced by a multitude of smallholders (with less than five cows in average) which commonly feed animals with crop residues and natural vegetation. This region knows critical erosion problems and soil fertility degradation (Douzet et al., 2008) which increased with cover-crop and land over-using for agriculture and livestock feeding. In these complex traditional farming systems, integrative and interdisciplinary modelling tools are needed for better understanding crop-livestock interactions and identifying a compromise between resources allocation for livestock production and soil fertility improvement. The purpose of this work is to build a biophysical whole-farm computer model (milk and crop yields) for simulating at the farm scale the various flows of biomass occurring between the different compartments (cattle, crops, stocks of organic plant material, soil, organic fertilizers, etc.) in these mixed farming systems.

Modelling

Modelling crop-livestock systems in tropical areas is still widely under-developed. Our objective is to assess the impact of changes in biomass allocation (animal feeding vs mulch) on production (milk production, crop yield) and environment (carbon sequestration, nitrogen availability, and soil fertility). We used the general framework exposed in Thornton and Herrero (2001) for the integration of detailed biophysical livestock sub-models (herd demographics, diet, milk yield, manure) and agronomic sub-models (water and nutrient cycles, grass growth and crop yields). This conceptual crop-livestock model follows the schematic representation of the agricultural systems components and their interactions (Thorne, 1998) and can be seen as a stock-flow model (compartment model): the stocks are animals, crops, land, plant organic matter and livestock manure, and the biomass circulating within the system are natural and cultivated fodders (including crop residue and mulch in conservation agriculture), crops, milk, animals, manure and plant nutrients.

We combined two models from the literature, (i) GAMEDE (Vayssières et al., 2009), a whole-farm model, developed in Reunion Island dairy herds to represent dynamically the effect of management decisions on various sustainability indicators, such as milk and forage crop productivity, labour requirements, nitrogen balance, and (ii) FIELD (Tittonell et al., 2008), a dynamic summary model of the soil-crop system that captures essential interactions determining crop productivity in smallholder farming systems in the sub-Saharan area. We needed to adapt the dairy module of GAMEDE to the local smallholder dairy system and to improve the soil, crop and manure modules (FIELD). Other supplementary modules were added to integrate common family constraints (cash and food requirements, workforce availability, etc.) and input-output flows generated by pig and poultry activities.

Data collection

Four mixed farms with different structures (agricultural land size, dairy herd size) and management strategies (conservation agriculture practices) are used for calibration and validation steps (Table 1). An 'immersion' approach (living on and participating in the daily activities), inspired by the ethnographic approach, has been adapted to access operational technical decisions and collect data in each farm on cropping and breeding practices, biomass allocation, manure management, social and economical constraints. Additional on-farm measurements were also needed for assessing fodder, soil and manure composition.

Table 1: Farm characteristics

Farm	Resource endowment	Agricultural land (ha)	Dairy cattle (head)	Permanent workforce (AWU)	Milk transaction	Diversification	Conservation Agriculture	Off-farm activities
A	poor	6	2	3.6	self-consumption	No	Yes	No
B	medium	4	7	6.9	sale	barley	No	No
C	rich	11	4	9.1	sale	pigs	Yes	Yes
D	rich	21	30	11.9	transform	pigs, poultry	No	Yes

AWU: Agricultural workforce unit

Conclusions

This model will ultimately be used to compare various strategies in biomass allocation and to identify key factors influencing the adoption of conservation agriculture (direct seeding mulch based cropping system) in smallholder farming systems in the Vakinankaratra region.

References

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